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## GRAHAM'S RESEARCHES

*Chemical and Physical Researches.* By Thomas Graham, D.C.L., F.R.S. Collected and printed for presentation only. (Edinburgh, 1876.)

IT is but seldom that science owes a work like this to private munificence. All, therefore, to whom Mr. Graham's memory is dear will be specially grateful to Mr. James Young for choosing, as the second monument he has raised to his friend, the publication of this splendid volume.

It is fortunate also that its compilation has been undertaken by Dr. Angus Smith, who has done more than collect the scattered writings, for he has added an analysis of the contents of the volume which cannot fail to be of use, and reminds us, in a careful preface, of Graham's claim to a place in "that chain of eminent thinkers which has been represented by such as Leucippus, Lucretius, Newton, Higgins, and Dalton." As the work is printed for private circulation only, it may be well to give a brief summary of this preface which is headed "Graham and other Atomists."

A sketch is first given of the nature of Indian and Greek thought as regards atoms, and, passing to Leucippus, Dr. Smith points out that "in the mind of this early Greek, the action of the atom as one substance taking various forms by combinations unlimited, was enough to account for all the phenomena of the world." Leucippus told us that all was motion. "Graham conceived the idea that the diversity in the motion was the only basis of the diversity of the material, or that an atom constituted an element of a special kind," according to the velocity or nature of its movements. After Leucippus few men seem to have devoted much attention to the subject until modern times. A quotation from Lange gives the position assumed by Democritus, "The difference of substances arises from the difference in the number, size, shape, and arrangement of the atoms. The atoms have no internal conditions; they act by pressure and percussion only."

Dr. Smith considers that the views of Lucretius deserve attention, as he was the only full expositor of the theory of atoms to the ancients. To Lucretius atoms are "solid and eternal, with some unalterable motion." "They are made of parts, which parts cannot exist by themselves." "Motion is to him everything that can be found in life and thought, which are only the clashing of atoms." This theory allows of any shape of molecules, even hooked ones, which, as Dr. Smith somewhat dryly adds, "are spoken of as explaining combination both in Lucretius and more modern writers." Space will not permit Newton's words to be given at length, but he held that the primitive particles of which matter is composed are incomparably hard and incapable of wear, for otherwise "water and earth composed of old worn particles, would not be of the same nature and texture now with water and earth composed of entire particles in the beginning." He is thus forced to the conclusion that "the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles."

A sketch is then given of the next important stage, namely, the motion of gaseous molecules, beginning with Daniel Bernoulli, and passing to Davy, Rumford, and Herapath—to whom, by the by, Graham asserted in 1863 the merit of reviving Bernoulli's hypothesis in modern times is fairly due. As is well known, the theory of gases now generally received makes them consist of small bodies continually impinging on one another, and on the walls of the inclosing vessel, their elasticity increasing with the temperature, and the pressure of the gas being due to the impact of the particles against any surface presented to them, an hypothesis which Joule investigated experimentally.

Now, as Dr. Smith shows, "it was the object of Graham's life to find out what the movement of an atom was. . . . He avoided picturing the most primitive motion in all its character, but he seems to indicate one of revolution, as he brings in the similarity to the orbit of a planet," and he advances still further, "when he adopts the theory of one kind of matter, each atom being distinguished by the extent of its motion," there being an initial impulse for each kind. "These atoms are believed to be congregate . . . and equal volumes can coalesce and form a new atomic group." Indeed the whole force of Graham's intellect was patiently and persistently devoted to this study of molecular movement, and as Dr. Smith claims him to be as "strict an anatomist as perhaps can be found," it may be interesting to gather from his writings some of the passages in which his views are expressed.

His earliest paper, on the Absorption of Gases by Liquids, was published in Thomson's "Annals of Philosophy," in 1826. In it he considers that "gases may owe their absorption in liquids to their capability of being liquefied," and that when gases appear to be absorbed by liquids, they are simply reduced to that liquid inelastic form, which otherwise (by cold or pressure) they might be made to assume; their detention in the absorbing liquid is owing to that mutual affinity between liquids which is so common. In his last paper in the *Phil. Trans.*, published forty years afterwards, he refers to the liquefaction of gas in colloids in much the same terms, for he alludes to the "general assumption of liquidity by gases when absorbed by actual liquids or by soft colloids," and he states that those gases penetrate (india-rubber) most readily which are easily liquefied by pressure, that gases undergo liquefaction when absorbed by liquids and such colloid substances as india-rubber, and finally, that the complete suspension of the gaseous function during the transit through india-rubber cannot be kept too much in view.

The *Quarterly Journal of Science*, 1829, pp. 74-83, contains his first paper on the diffusion of gases. In it he states that the diffusiveness of gases is inversely as some function of their density, apparently the square-root of the density; he also considers it conceivable that orifices of excessive minuteness may be altogether impassable by gases of low diffusive power, but defers these theoretical considerations to a future paper. This promise was fulfilled by a paper in 1831, the object of which was to establish the following law of the diffusion of gases. "The diffusion or spontaneous intermixture of two gases

in contact is effected by an interchange in position of indefinitely minute volumes of the gases, which volumes are not necessarily of equal magnitude, being in the case of each gas inversely proportional to the square root of the density of that gas." He speaks of diffusion "being effected by a force of the highest intensity," and insists that diffusion takes place between the *ultimate particles of gases*, and not between sensible masses. In a later paper, *Phil. Trans.*, 1863, he states that molecules only of gas can pass the pores of graphite, "and they may be supposed to pass wholly unimpeded by friction." He showed that a gas may pass into a vacuum in four ways, first by effusion, a movement which affects *masses* of gas only, second, by diffusion which affects *molecules*, third, by transpiration through capillary tubes, "the transpiration ratios forming a class of phenomena remarkably isolated from all else at present known of gases," and lastly by a previous absorption in the walls of the septum which divides the gas from the vacuous space, as was so beautifully shown in the papers published in the years 1866-69. In one of these, in considering the passage of gas through metallic septa, he recognises "an intermolecular porosity due entirely to dilatation at a high temperature," and thus apparently hoped to ascertain the ultimate size of molecules, for he says that this "species of porosity, if it exists, might well be expected to throw light on the distances of solid molecules at elevated temperatures."

His views are very clearly defined in a paper published in 1863 entitled "Speculative Ideas respecting the Constitution of Matter." He is of opinion that the various kinds of matter now recognised as different elementary substances may possess one and the same ultimate or atomic molecule existing in different conditions of movement. Were this ultimate atom at rest, the uniformity of matter would be perfect; but it always possesses motion, due to a primordial impulse, and, as differences in the amount of this motion occasion differences of volume, matter only differs in being lighter or denser matter. The gaseous molecule is composed of a group of the preceding inferior atoms following similar laws and is thus a reproduction of the inferior atom on a higher scale. Chemical combination consists in equal volumes of the different forms of matter coalescing and forming a new atomic molecule, and is therefore directly an affair of weight; and the combining weights differ because the densities, atomic and molecular, differ. Graham is further careful to point out that liquefaction and solidification probably only involve a restriction of the range of the atomic movement.

In this brief sketch it has not been possible to touch on his views as to states of matter, such, for instance, as the "colloidal condition which intervenes between the liquid and crystalline states," or to the more purely chemical portion of his work, of which his theory of polybasic acids is probably the most remarkable.

Widely as the value of Graham's work was recognised during his lifetime, there is no doubt that the appreciation of it is increasing, and cannot fail to be stimulated by Mr. Young's liberality, which has set forth the researches in such a manner as to impress us with their coherence and strength.

W. CHANDLER ROBERTS

## THE ANDES AND THE AMAZON

*The Andes and the Amazon; or, Across the Continent of South America.* By James Orton, A.M., Professor of Natural History in Vassar College, U.S., &c. Third Edition, Revised and Enlarged, containing Notes of a Second Journey. Maps and Illustrations. (New York: Harper Brothers, 1876.)

AS is indicated in the title this work contains accounts of two separate journeys, to a considerable extent over the same ground, the first undertaken in 1867, the second in 1873. A narrative of the former was published several years ago both in America and in England, we believe; the second half of the volume is quite new and is essentially supplementary to the former. The results of the journey of 1867 are given in the form of a personal narrative, those of 1873 are arranged systematically in a number of chapters on the various features of the Amazon and its surroundings. The main scientific results of both expeditions have been described in the *Proceedings* of various scientific societies and in scientific journals in America and in England, and the present volume is therefore perfectly free from any details that would prove unattractive to the general reader.

In the journey of 1867 Prof. Orton and party landed at Guayaquil in Ecuador, mounted the Andes to Quito, proceeded by Papallacta, Baeza, and Archidona, still among the Andes, to the Napo river. Floating down this river they reached the Amazon, took steamer at Pebas, and enjoyed a splendid sail to the mouth of the river at Pará. In the second journey, that of 1873, Prof. Orton landed at Pará and sailed up the great river to Yurimaguas, thence over the Andes to the Pacific Coast and down to Lima, with a side-excursion to Lake Titicaca by way of Arequipa.

Prof. Orton tells his story in most attractive style. He is in danger sometimes, no doubt, of degenerating into the florid, but from beginning to end of his large volume he never ceases to be attractive, amusing, and instructive. He writes on people and things in the wonderful region of the Amazon with great piquancy, genuine humour, and full knowledge; he frequently becomes absolutely eloquent, if not poetic. Few features of the towns and the country through which he passed have escaped his attention. In describing his first journey, he lingers at Quito for several chapters, describing the city, giving hints and comments on its history, touching off the appearance and character of its easy-going people, giving an account of the country of which it is the capital, Ecuador, the flora and fauna and primeval inhabitants of the Valley of Quito, rising thence to an eloquent dramatic sketch, *à la* Hugh Miller, of the geological history of South America, the rise of the Andes, and the creation of the Amazon, devotes two interesting chapters to the volcanoes of Ecuador and its earthquakes, and before leaving, gives several details about a few of the Indian tribes in "the Province of the Orient." So on his way down the Napo and the Amazon, he paints vividly and picturesquely the scenery, the people, the animals, the plants, and the geology of one of the most interesting regions in the world. He chats pleasantly and piquantly of all he comes across, never gives the reader a chance of feeling wearied, and leaves him, if he has been a faithful